Skagit Rule Amendment
Background on the Reservations, Closures, and Hydraulic Continuity

Prepared in support of the proposed amendment to:

Chapter 173-503 WAC
Instream Resource Protection Program –
Lower and Upper Skagit Water Resource Inventory Area (WRIA 3 and 4)

January 3, 2006

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This paper documents the background policy and technical basis for three aspects of the proposed amendment to Chapter 173-503 WAC, the *Instream Resource Protection Program – Lower and Upper Skagit Water Resource Inventory Area (WRIA 3 and 4)*:

- **Reservations-** the policy and technical basis of the reservations and the intended administration are explained.
- **Closures**- the basis and administration of closures of several tributary subbasins in the Skagit River are explained.
- **Hydraulic Continuity-** the policy and technical basis on hydraulic continuity in the Skagit Basin is explained.

RESERVATONS

The proposed Skagit rule amendment would reserve approximately 25 cubic feet per second for future water uses in the Skagit Basin. The amount of water is divided into two reservations that would not be subject to the instream flow. A reservation of 10 cfs, which is equivalent to 3,564 acre-feet annually has been proposed for agricultural irrigation. A reservation of 15 cfs, which is equivalent to 10,840 acre-feet annually has been proposed that would be divided among 25 sub-basins for year-round future domestic, municipal, commercial/industrial and stock watering uses.

In managing water resources Ecology must both protect and preserve fish and wildlife and provide water for agriculture, industry and human domestic use. In the Skagit Basin, an instream flow was established in 2001 to preserve and protect in-stream resources. All water uses, including permit-exempt groundwater uses, established after the instream flow rule are junior to the instream flow and may be subject to interruption when instream flows are not met. Based on past flow records, it is clear that instream flows are not met and interruption may be necessary during nearly every month of the year (see figure 1). Homes and businesses need a year-round reliable water supply to satisfy basic human needs. An interruptible supply cannot serve this need. Farmers need reliable water supply during the irrigation season to grow their crops. An interruptible water supply may or may not be a reliable supply for most farmers, depending on the crop grown.

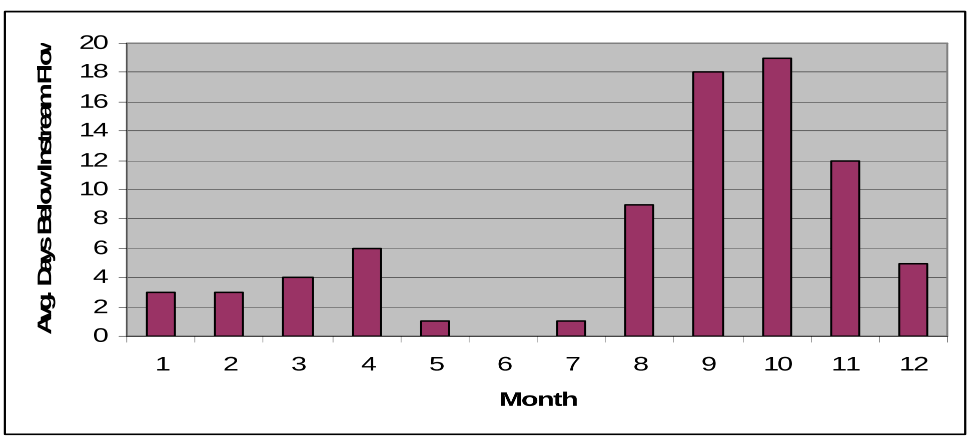

Figure 1. Average Number of Days Existing Flows Would Have Been Below Minimum In-Stream Flows Established in Chapter 173-503 WAC (Period 1941-2003)

The purpose of the reservations is to establish an uninterruptible supply of water that will be available to serve out-of-stream needs in the Skagit Basin. The reservations are divided according to different purposes of use and the allocated amounts are distributed into sub-basins. Additionally, the reservations are available under some strict conditions. The use of reserved water is not subject to instream flows, meaning it is not interruptible.

Legal Basis of the Reservations

An uninterruptible supply of water for future out-of-stream needs is based upon RCW 90.54.020 (3)(a). This section creates an exception to minimum instream flows when a clear showing of "overriding considerations of public interest" (OCPI) is made. RCW 90.54.050(1) authorizes Ecology to reserve or set aside through rulemaking waters for future beneficial uses. The appropriate statutory mechanism for identifying and creating an amount of water to serve out-of-stream purposes is a reservation. Additionally, Ecology is directed under RCW 90.54.020 (2) to allocate waters among potential uses to secure the maximum net benefits for the people of state, considering economic and aesthetic and environmental benefits.

Four part test

To establish a reservation, Ecology must apply the statutory four part test for a water right since the reservation constitutes an appropriation (RCW 90.03.345). Ecology's applications of the four part test (RCW 90.03.290, RCW 90.44.100) are below:

(1) *Water is available to meet the proposed use*–The legal test related to water availability includes the physical and legal availability of water. Water is generally *physically* present and available throughout the areas covered by the reservation. When water is physically present but withdrawal would impair a senior appropriation to instream flows, it is *legally* unavailable. Ecology's basis for finding that water is available and overriding the legal unavailability is a conclusion that OCPI exists.

(2) *The proposed use is beneficial* – RCW 90.54.020 (1) states that use for domestic, municipal, irrigation, commercial/industrial and stock watering are considered beneficial uses of water.

(3) *It is non-detrimental to the public welfare* – The legislature has directed Ecology to manage water in order to provide sufficient water supplies to meet the needs of people, farms and fish (RCW 90.54.005). Ecology is also directed to allocate water in a manner that maximizes net benefits for the people of the state. Should any conflict of these public interests exist, they are addressed as part of the OCPI analysis.

(4) *The proposed use will not impair existing water rights (including instream flows rights)* – Any groundwater withdrawals or surface water diversions that might capture surface water or use surface water may impair instream flows when instream flows are not being met. However, as above, this conflict with instream flows is addressed in the OCPI analysis.

Overriding Consideration of Public Interest

RCW 90.54.020(3)(a) generally prohibits Ecology from allowing withdrawals of water from surface or groundwater that conflict with instream flow needs. Withdrawals with potential conflict may be allowed only if there is a clear showing of overriding consideration of public interest. Ecology is using this narrow exception to address conflicts arising from the four part test to establish the reservations in the Skagit Instream Flow Rule proposal.

In making a statutory determination of OCPI under RCW 90.54.020(3)(a), Ecology uses a three step analysis:

1. Ecology determines whether and to what extent important public interests would be served by the proposed appropriation. The public interests served may include benefits to the community at large, such as providing water for homes, businesses and farms, as well as environmental benefits such as fish and wildlife habitat, scenic, aesthetic, recreational and navigational values.

2. Ecology assesses whether and to what extent the proposed appropriation would harm any public interests, including economic and environmental benefits.

3. Ecology determines whether the public interests served (as determined in step 1) clearly override any harm to public interests (as determined in step 2).

The three-step analysis for the proposed Skagit rule amendment is below.

1. Ecology determination of whether and to what extent important public interests would be served by the proposed reservation.

The legislature has directed Ecology to allocate waters of the state in order to secure the maximum net benefits for the people of the state. Benefits and costs include both economic ones and environmental and aesthetic benefits and costs. Ecology is also directed in RCW 90.54.020 to seek expressions of the public interest at all stages of water planning and allocation decisions. Comments received from the public and key stakeholders indicate a significant public interest in having secure water supplies for domestic and municipal, agricultural irrigation, commercial/industrial, and stock watering uses, in addition to providing water for instream purposes. The creation of the reservations will allow residents, businesses and farms to use water for those purposes during low flow periods without interruption. As was noted in Figure 1, it is likely that low flow periods would occur about 2/3 of the time during some months under the existing rule. Legally, those households, businesses and farms obtaining water without the proposed reservation could be required to completely curtail use in times of low flow. Curtailing use would have economic and human health impacts to residences, businesses and farms. For most users, an interruptible water right could not be considered a reliable water source. The proposed rule amendment will eliminate the cost of constructing storage and treatment for use during interruption periods. This avoided cost can be viewed as a measure of the benefit of this rule amendment. Using this avoided cost as a measure of benefit, Ecology has preliminarily estimated that the probable economic benefit for the proposed rule amendment is more than $32.9 million in a 20-year time horizon.

2. Public interests that would be impacted by the proposed appropriations for the reservations.

As the reservation allows for further withdrawal of water, the creation of the reservations could impact instream uses such as aquatic resources and some associated recreational uses. Ecology has designed the reservations to minimize potential impacts to aquatic resources and recreational uses. The following provisions are critical to avoid and minimize impacts to stream flows from the reservations:

- The size of the reservations has been minimized to protect fish.
- Commercial and domestic needs must first be met from existing public water systems (this provision is discussed in greater detail later in this document.).
- Water use efficiency is required.
- Closure of water-limited basins for consumptive water use once the reservations are fully allocated (this provision is discussed in greater detail later in this document).
- Measuring and reporting of water use.
- Uses in smaller tributaries are limited to groundwater sources only.
- Seasonal agricultural irrigation water rights cannot be converted to another purpose resulting in a year-round water use.
- Uses in important salmon tributaries in the Upper Skagit watershed, WRIA 4, are limited to groundwater use only and are limited in quantity to only 25,851 gpd per tributary basin.

Most importantly, the size of the reservations has been kept very small to minimize potential impacts on fish and river ecosystem functions. The size of each of the reservations has been limited to amounts that Ecology and WDFW fish biologists believe are unlikely to significantly impact the long term sustainability of the fish population. The basis of the biological judgment is discussed later in this document. Additionally, the reservation has been sized to prevent any measurable reduction in aesthetic, navigational or recreation values.

3. Public interests advanced by the proposed appropriation clearly override the public interest impacted.

Based on Ecology’s determination that (1) the important public interest of providing reliable supplies of water for domestic, municipal, agricultural irrigation, commercial/industrial and stock watering needs is significantly served by the reservations, and (2) that the public interest of protecting instream flows is not significantly impacted when use of water under the reservations is limited as here, Ecology therefore finds that there is a clear showing of overriding consideration of public interest under RCW 90.54.020(3)(a).

Size of the Reservations

The size of the reservations is limited to the amount of water determined to avoid significant biological impact in the sub-basin in question. This section explains how the reservation quantities for the Skagit sub-basins have been determined.

Sub-basins

The Skagit River is one of the largest river systems in Washington State. It is classified by the state of Washington as consisting of two different Water Resource Inventory Areas (WRIA). WRIA 3 is the Lower Skagit River Basin and WRIA 4 is the Upper Skagit River Basin. Ecology has further divided the Skagit basin into a number of sub-basins for the purpose of administering this reservation (see figures 2 and 3). In WRIA 3, the sub-basins are based on independent tributaries to the Skagit River. In some cases, small tributary basins in close proximity to one another are combined for ease of administration. The mainstem of the Skagit River is divided into the Lower Skagit, Middle Skagit, and Upper Skagit sub-basins. In WRIA 4 (Upper Skagit sub-basin), Grandy creek is the only tributary that has a separate reservation. The remainder of WRIA 4, the mainstem Skagit and its tributaries, constitute the Upper Skagit sub-basin. Several tributaries have been delineated in WRIA 4, but they do not have separate tributary reservations, with the exception of Grandy Creek (see figure 3). Instead, water use in those tributaries is limited to 25,851 gallons per day of groundwater, but this limitation is not a reservation. Water use in those WRIA 4 tributaries will be subtracted from the total Upper Skagit sub-basin reservation. The Upper Skagit sub-basin is treated as a single large sub-basin based on the expected patterns of demand for domestic or commercial water. In most of the Upper Skagit basin water use is likely to occur in limited area generally in areas in close proximity to the mainstems of the Skagit and Sauk rivers. In general, much of the Upper Skagit basin is in public ownership and is unlikely to experience much demand for residential and business water uses.

The sub-basin delineations are based on input from Skagit County, Swinomish and Sauk-Suiattle Tribes and Ecology (Skagit County 2004b). The delineations largely follow surface characteristics, but in the lower reaches, the delineations are modified in some cases to follow roads or property lines. This is done for easier administration of the rule.

Figure 2

Map of WRIA 3, Lower Skagit Sub Basins

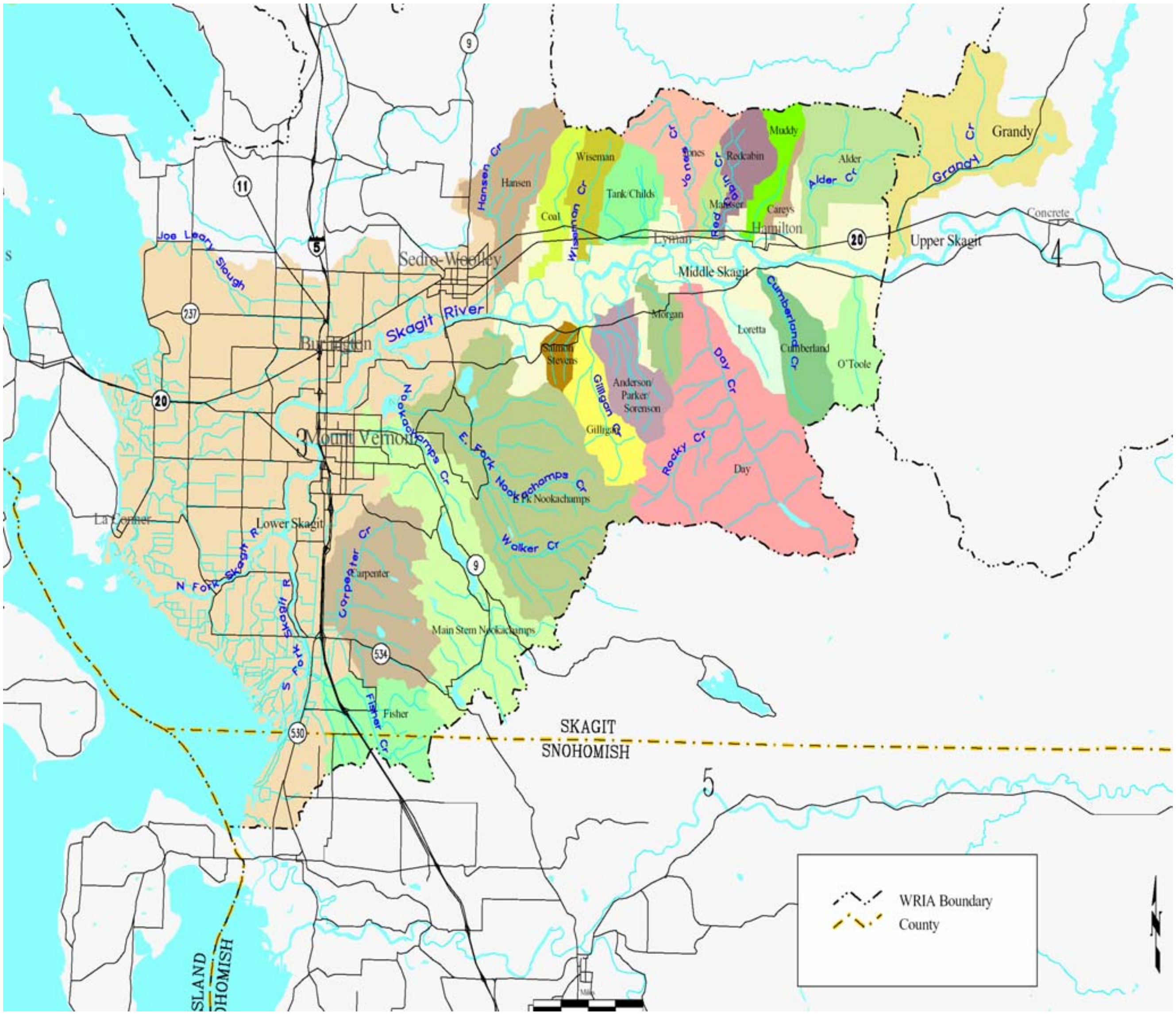

Figure 3

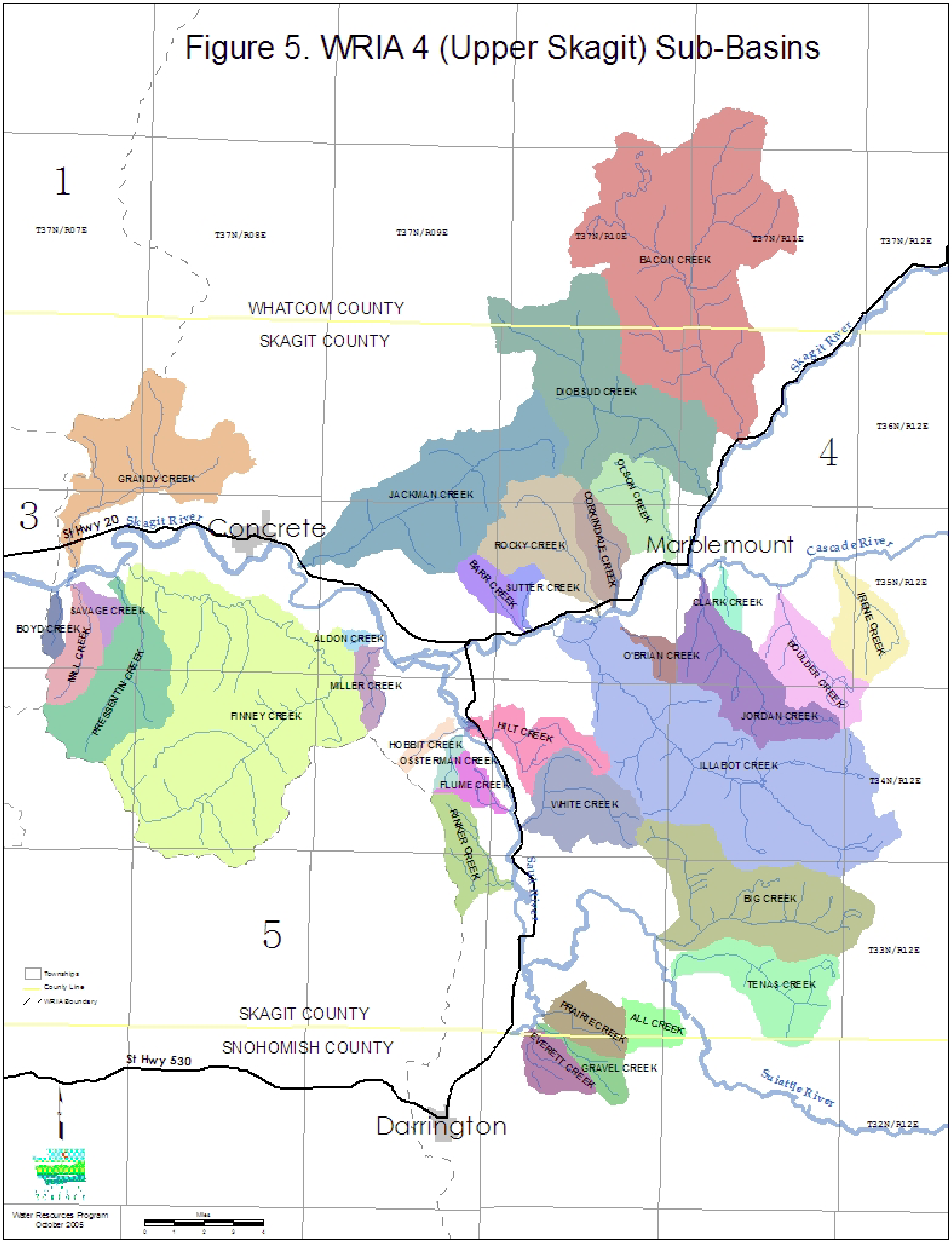
Figure 5. WRIA 4 (Upper Skagit) Sub-Basins
1
3
4
5
T37N/R07E
T37N/R08E
T37N/R09E
T37N/R10E
T37N/R11E
T37N/R12E
T36N/R12E
T35N/R12E
T34N/R12E
T33N/R12E
T32N/R12E
WHATCOM COUNTY
SKAGIT COUNTY
SNOHOMISH COUNTY
BACON CREEK
DIOBSUD CREEK
GRANDY CREEK
JACKMAN CREEK
ROCKY CREEK
OLSON CREEK
CORKINDALE CREEK
BARR CREEK
SUTTER CREEK
SAVAGE CREEK
BOYD CREEK
MILL CREEK
PRESSENTIN CREEK
FINNEY CREEK
ALDON CREEK
MILLER CREEK
CLARK CREEK
IRENE CREEK
BOULDER CREEK
O'BRIAN CREEK
JORDAN CREEK
ILLABOT CREEK
HILT CREEK
HOBBIT CREEK
OSSTERMAN CREEK
FLUME CREEK
WHITE CREEK
RINKER CREEK
BIG CREEK
TENAS CREEK
PRAIRIE CREEK
ALL CREEK
EVERETT CREEK
GRAVEL CREEK
St Hwy 20
Skagit River
Concrete
Marblemount
Cascade River
Sauk River
Suiattle River
St Hwy 530
Darrington
Townships
County Line
WRIA Boundary
Water Resources Program
October 2005

Basis for Reservation Quantities

Ecology, in consultation with its biologists and the Department of Fish and Wildlife biologists, determined that the reservation quantities in Table 1 for 25 streams would have little impact on the long term sustainability of the fish population in the tributaries and affected downstream reaches. This determination is based on a number of factors including: knowledge of fish life-stages and their dependence on stream flows and the projected consequences of small depletion in stream flow (described below). Reservation quantities were also influenced by assessments of future water demand, pending water rights applications, and from input by some stakeholders in the Skagit basin.

Stream flow depletions

The reservation quantities were generally determined by the projected consequences of small depletions of stream flow. Biologists from Ecology, in consultation with the Department of Fish and Wildlife, determined that the reservation withdrawals (see Tables 1 and 2) would cause a loss of 0.5% to 2% of habitat during a bad case scenario such as during a low flow month like September during a low flow year (i.e. a 90% monthly exceedence flow). This small reduction in habitat would have little impact on the fish population. These percentages of habitat loss would be much smaller during the other months of the year when higher flows exist.

The impact on the fish in a normal year (median monthly flow) would be approximately half of the effect during a low flow year. The impact in a normal year would be on the order of 0.05% to 1% loss of habitat, but only during the lowest flow month of September and much less during the other months. This is because taking a flow from the stream during a median flow would be a much smaller percentage of the flow and would result in a much smaller impact on fish habitat than taking the water during a low flow time, such as September.

Since stream flows are generally most important for fish during the lowest summer flow events, the biologists reasoned that if the effect of a flow reduction during the low flow events was very small, then the overall reduction at other times would likely be even smaller. A small loss of fish habitat on the order of 1 to 2% has been calculated on other streams where IFIM/PHABSIM fish habitat studies have been done in Washington. Ecology biologists have found that a 1% - 2% loss in habitat closely corresponds with a 1% - 2% loss in steam flow during low-flow conditions (September 90% exceedence flow). Therefore a 1% to 2% loss in streamflow during a low flow month such as September can serve as a reasonable surrogate for estimating the 1% to 2% loss in fish habitat.

Tributary Sub-basin Reservation Sizes

Following the reasoning above, Ecology used a flow statistic known as 7Q10 as representative of low-flow conditions in the tributary sub-basins of WRIA 3 for the Lower and Middle Skagit River. 7Q10 is the lowest consecutive seven day flow to occur an average of every ten years and is generally comparable to a 90% exceedence flow during a low-flow month. Ecology calculated 7Q10 flows for several gauged streams in and near the Skagit basin. A relationship between

7Q10, drainage area, precipitation, and general geology was then developed. Ecology then applied this relationship to each of the Skagit tributary sub-basins to estimate 7Q10 flows. Attachment 1-3 contain more detailed descriptions of how the estimates were calculated. Table 1 shows the estimated 7Q10 results.

Ecology considers 2% of the 7Q10 flows as a potential indicator of the upper limit on reservation size when determining the reservation quantity (Table 1). This is a quantity of potential stream flow depletion that Ecology judges to be a very small impact on the long term sustainability of the fish population and is very protective of fish while also providing for out-of-stream water uses. Table 1 lists the reservation quantities contained in the rule proposal. It is important to highlight that the reservation quantities are defined as the maximum average consumptive daily use which represents the consumed quantity of water, rather than just the amount of water of water taken out of the ground or surface water source. The concept of consumptive water use is discussed later in this document. The reservation quantities may not always meet the projected demand in some sub-basins. In those cases, public water or other sources may be required.

Table 1. Tributary Reservation Quantities

Sub-basin management unit	Estimated 7Q10 flow Cubic feet per second	2% of 7Q10 flow Cubic feet per second	Reservation Quantity Maximum Average Consumptive Daily Use Gallons per day
Alder Creek	6.3	0.126	**81,430**
Anderson / Parker /Sorenson	1.6	0.031	**20,034**
Careys	0.9	0.018	**11,633**
Carpenter	0.5	0.01	**6,463**
Childs/Tank watershed	1.4	0.028	**18,096**
Coal	1.4	0.029	**18,742**
Cumberland	2.0	0.04	**25,581**
Day	10.2	0.204	**131,839**
Fisher	0.4	0.008	**5,170**
Gilligan	2.0	0.04	**25,851**
Grandy	11.4	0.228	**147,350**
Hansen	2.9	0.059	**38,130**
Jones	5.2	0.104	**67,212**
Loretta	0.9	0.018	**11,633**
Mansser	1.2	0.024	**15,511**
Morgan	1.0	0.021	**13,572**
Muddy	2.2	0.044	**28,436**
Nookachamps - East Fork	1.1	0.022	**14,218**
Nookachamps - Mainstem	0.8	0.019	**12,279**
O'Toole	1.8	0.036	**23,266**
Redcabin	3.3	0.066	**42,653**
Salmon/Stevens watershed	0.4	0.008	**5,170**
Wiseman	1.4	0.028	**18,095**
Total		**1.211**	**782,364**

Mainstem Reservation Sizes

In the mainstem sub-basins, the two reservations were developed with consideration of three factors: the biological consequences of withdrawals, water demand forecasts, and by input from some stakeholders. The mainstem reservations were limited by the stream flow depletion threshold, of 1-2% of the low stream flow. In total, the reservations are well below the 1-2% threshold, and in total represent less than 0.5% of low flow conditions (the 90% exceedence flow). Tables 2 and 2.1 list the mainstem reservation quantities and the reservations in proportion to stream flow conditions.

Mainstem Domestic, Municipal, Commercial/Industrial and Stock Watering Reservation

The mainstem sub-basins reservations were also developed from future water demand assessments. Skagit County has conducted assessments of water demand based primarily upon population forecasts for the County. Using these forecasts and some assumptions about commercial and industrial water needs, the county estimated water needs from 2-9 cfs for 2025, 7-31 cfs for 35 years, 15-61 cfs for 45 years, to 33-80 cfs for 50 years for land in the Skagit River basin (Greenberg 2005(a), Greenberg 2005(b)). The county's assessment also divided the population and associated water demand into sub-basins, this assisted to shape the mainstem reservation budgets, and inform if tributary reservation budgets would meet the projected demand.

The reservation quantity of 15 cfs was developed based on specific water demand projections. Under the Skagit County preferred growth rate, water demand forecasts done by Skagit County in March 2005 projects a water demand shortfall of 10.3 million gallons per day or 15.93 by 2050 (Greenberg 2005(a)). However, the water demand estimates conducted by Skagit County are for the maximum day demand. Maximum day demand is the highest amount of water needed to meet the maximum demand of a year, such as a hot summer day when many users would irrigate lawns and gardens. A maximum day demand of 15.93 cfs represents a much lower average daily water demand, which is how the reservation will be administered. Ecology believes that the proposed reservation quantity of 15 cfs likely meets the projected demand because the amount of water debited against the reservation is not the actual amount of water withdrawn from the water source, instead the quantity of water deducted is the maximum average consumptive daily water use. Ecology has defined the maximum average consumptive daily use in the rule proposal as the amount of water measured over the highest period of use divided by the number of days in that period, less the septic recharge return flow credit. This concept is described in more detail later in this document. However, the critical concept in assessing the adequacy of the reservation is evaluating average daily water use. The likely water measurement period of time is monthly, especially during the periods of the year where demand is high and stream flows are low (August, September, October). This means that the total water use recorded each month will be averaged between the days of month and any applicable septic return flow credit will be applied for the total to be deducted from the reservation. An example of how the water measurement and return flow recharge credit will be applied is provided later in this document.

Estimating long-term water demand is difficult and there is some uncertainty involved with the estimates. The County's estimates represent the best forecasts that could be done with the data at hand, but it is important to highlight some of the limitations with the water demand forecast. Population forecasts are done by geographic boundaries, and there could be some error associated with distributing the population into sub-basins. Additionally, available population forecasts generated by demographers such as those provided by the Office of Financial Management (OFM) go to only year 2025. Skagit County's consultant had to extrapolate the population forecast in the long term from the 2025 growth rates, assumptions which could be erroneous.

Table 2. Mainstem Domestic, Municipal, Commercial/Industrial and Stock Watering Reservation

Sub-basin management unit	Reservation Quantity Cubic feet per second	Reservation Quantity Maximum Average Consumptive Daily Use Gallons per day
Skagit-Lower	**8.631**	**5,578,103**
Skagit-Middle	**2.158**	**1,394,655**
Skagit-Upper*	**3.0**	**1,938,816**
Total	**13.789**	**8,911,574**

**All uses in each Upper Skagit tributary sub-basin identified in Figure 5 of WAC 173-503-120 (Figure 3) are limited to a maximum average consumptive daily use of 0.04 cfs or 25,851 gallons per day. These uses will be debited against the Upper Skagit tributary sub-basin reservation quantity.*

Table 2.1 Mainstem Skagit Low Flow Estimates and Reservation Quantities

Sub-basin management unit	Estimated Low Flow (September 90% Exceedence Flow) Cubic feet per second	Reservation Quantity Cubic feet per second	Percentage of Low Flow	Reservation Quantity Maximum Average Consumptive Daily Use Gallons per day
Skagit-Upper	**3,879@Marblemount**	**3.0**	**0.08**[(1)]	**1,938,816**
Skagit-Middle	**5,270@Concrete**	**2.158**	**0.04**[(1)]	**1,394,655**
Skagit-Lower	**5,970@Mount Vernon**	**8.631**	**0.14**[(1)]	**5,578,103**
Skagit-Tributary Sub-basins	**(see Table 1)**	**1.211**	**2.00**	**782,364**
Skagit-Ag Irrigation*	**5,970@Mount Vernon**	**10.0**	**0.16**	**6,462,720**
Total	**5,970@Mount Vernon**	**25**	**0.42**[(2)]	**16,156,658**

***Seasonal reservation for irrigation season (180 days)**
[(1)] For this reach of the river
[(2)] Additive for the basin

Mainstem Agricultural Irrigation Reservation

The agricultural irrigation reservation is limited to only the mainstem sub-basins. The reservation was sized to stay below the 1-2% stream depletion threshold, as previously discussed, and was also shaped by assessing future agricultural irrigation demand. Irrigation water rights are seasonal rights, typically authorizing irrigation through the irrigation season. In Western Washington, the irrigation season is approximately 180 days, corresponding to a 6 month period which generally corresponds to April through the end of September. The instantaneous withdrawal rate is the rate at which the applicant can withdraw water from a well or a surface water body. The annual volume limit is assigned based on the projected irrigation need throughout the irrigation season, assigned using the water needs for the crops, with some allowances for application inefficiencies of the sprinklers.

The agricultural reservation proposed is for 10 cubic feet per second. 1 cfs, diverted continuously, is equivalent to 1.98 acre-feet per day. Consequently, 10 cfs is equivalent to 19.8 acre-feet per day, with an irrigation season of 180 days, the annual volume limit for a 10 cfs reservation equates to 3,564 acre feet. According to water demands for typical crops grown in the Skagit Basin, the average water duty for crops grown in the Skagit Basin is approximately 1.5 acre feet/acre (Greenberg 2005, HDR 2005). Based on these assumptions, the proposed reservation of 10 cfs would cover an additional 2,376 acres.

Skagit County has assembled some data on current irrigation demand in the Skagit River Basin from crop surveys and the USDA's agricultural census (Greenberg 2005c). They have also projected a low and high estimate of irrigation demand for 2050. The following table summarizes their findings.

Table 3. Estimated Agricultural Irrigation Water Demand

Demand	**Acres**	**Water Duty**	**Volume of water needed (acre feet)**	**Volume Equivalent in cfs**
Existing	14,732	1.14	16,784	47
Low End 2050	25,000	1.14	28,482	80
High End 2050	52,000	1.14	59,280	166
Water Rights				
Existing Permits and Certificates	11,017	1.58	17,408	48.8
New applications	5,405	1.58	8,450	24

If all of the permits and certificates are valid rights, then the current demand is covered by existing water rights. Skagit County has estimated that 194 cfs is claimed under claims to vested water rights. Of the new applications, it is very likely that many of the applications are to cover acres already in production and are being irrigated, and are part of the 14,732 acres. Consequently, the actual future demand may be less than is projected in the figures presented in this table, and it may be able to be met by a variety of tools such as transfers or changes to existing water rights, interruptible water rights, purchasing water from water utilities, or short term seasonal leases. For instance, more than 60% of the irrigation water demand in the Skagit Basin irrigation season is in the months of April-July. In these months, instream flows are met most days and water rights would be interrupted on average for only a few days per month (Figure 1). Consequently, interruptible water rights may meet the irrigation needs for certain crops in the Skagit Basin.

The proposed agricultural reservation should be able to meet a significant portion of the actual demand for new agricultural irrigation water. It will take some additional analysis to determine the actual existing and future demand for irrigation water and the validity of existing water rights and claims. Ecology is working with the CIDMP group to better understand the irrigation demand and develop solutions to meet the demand.

Conditions of the Reservation

The reservation contains several conditions. Ecology's basis for determining some of those conditions is discussed below

Connection to Public Water

Under the reservation, new domestic uses must obtain water from a public water system rather than from the reservation if the service is available in a "timely and reasonable manner." Ecology established this condition to avoid additional potential impacts to stream flows when possible. Furthermore, this condition supports the goals of RCW 90.54.020(8), which encourages the development of water supply systems which provide water to the general public. Ecology has deferred to local definitions of timely and reasonable, which can be defined in a coordinated water system plan developed under the Public Water System Coordination Act (RCW 970.116), by public water systems or by local legislative authorities.

Measuring Water Use

Ecology will keep a record of all water withdrawals from the reservation. All uses under the reservations, including permit-exempt ground water wells, are required to measure water use. For accounting purposes, Ecology will use water use information obtained from water source metering. If water metering data have not been provided to Ecology, household water use will be assumed to be 800 gpd and commercial use will be assumed to be 5,000 gpd per connection for accounting of the reservations. These figures were developed based on the Department of Health's domestic water planning figures and the limitation of the ground water permit-exemption. Ecology may also choose to use the best available information from sources such as well logs, building permits, water right permits, or public water system approvals to estimate water use.

The actual amount of water deducted from the reservation budgets may not be the recorded water use. Ecology is proposing to deduct from the domestic, commercial/industrial and stock watering reservation the maximum average consumptive daily use. This term means the use of water measured over the highest period of use divided by the number of days in that period, less the septic return flow recharge credit. For uses under the agricultural irrigation reservation, the amount of water deducted from the reservation will be based on metered water use and water rights issued by the department.

As previously discussed, the domestic, municipal, commercial/industrial and stock watering reservation is structured to account for consumptive water use. The reservation will be managed so that the maximum average consumptive daily use is debited from the reservation quantities. Ecology will reduce the estimated water consumed from the reservation by 50% per household or business connection to account for septic return flow. To illustrate the concept of the maximum average consumptive daily use an example is provided. If the water meter for the month of July reads 12,400 gallons, then the average daily water use for the month equates to 400 gpd (12,400 gallons / 31 days). If the household has an on-site septic system, a 50% septic recharge credit would be assigned to the water use. Thus, the maximum average consumptive daily use would equal 200 gpd, after factoring in the 50% septic recharge credit. The quantity of 200 gpd would represent the actual amount debited from the reservation.

In areas served by an on-site septic system, a portion of the water used by a home infiltrates to the ground via the septic system. The amount returned depends on site specific factors such as household water usage patterns, soil types, vegetation, and septic design. Ecology is using the 50% return flow estimate as a conservative assumption based on an analysis prepared by the consulting firm Economic and Engineering Services (EES 2002). The analysis used hydrologic principles and basic water use assumptions to look at four different water use scenarios –low water use; medium water use; high water use and maximum water use. Overall, the percentage of recharge decreases significantly as the amount of outdoor landscape irrigation increases. The medium water use scenario analyzed return flow to the aquifer from water-use inside the household based on three people per household using 70 gallons per person per day for inside use and irrigation of 50’ x 50’ or 2500 square feet of lawn and garden, as representing typical uses in the basin. The return flow from this scenario is estimated to range from 51% to 72%.

For water uses established after the existing Skagit Instream Flow was effective (April 14, 2001) and before the proposed rule amendment is effective, Ecology will not require those users to measure their water use. Those users will obtain the benefits of the reservations (an uninterruptible supply), and their water use will be deducted from the appropriate reservation at an amount equal to the average consumptive daily household water use for the Skagit River basin for domestic water uses, and at an amount of 5,000 gpd for commercial/industrial uses, unless actual water use records are available.

Local administration of the rule

Local jurisdictions, such as counties and cities, are required to share in the administration of this rule. Ecology’s basis for requiring local jurisdictions to share in the administration of the reservation if it is to be available is twofold. First, local governments have a role and responsibility in ensuring that new development has an adequate quantity of potable water. RCW 19.27.097(1) requires each applicant for a building permit that requires potable water to provide evidence of an adequate water supply for the intended use of the building. RCW 58.17.110 requires a county or city to determine that provisions for potable water supplies are made prior to approving a subdivision or a dedication (e.g., park).

Second, counties and cities by virtue of their existing role in reviewing and approving building permits and subdivisions are better equipped than Ecology to identify new water uses early that qualify for the reservation, to inform applicants of the terms of the reservation, and to work with applicants to make sure their proposals are consistent with the reservation. Local administration also provides for those with permit-exempt withdrawals from the reservation to proceed without approval from Ecology. This will provide for better implementation of the reservation and reduced confusion for those who seek to use water from the reservation.

CLOSURES

Ecology, in consultation with the Department of Fish and Wildlife, has determined that certain tributary sub-basins to the Skagit River should be closed when the reservations are fully allocated. A closure is a determination that no surface water, or ground water that contributes to surface water, is available for consumptive purposes. There are two kinds of closures. One is an administrative closure, which is a closure established by Ecology through an administrative rule. The second closure is one initiated by recommendation from the Department of Fish and Wildlife under RCW 77.55.050. The second kind of closures is referred to as Surface Water Source Limitation (SWSL) closures. Table 4 shows the sub-basins that Ecology is proposing to close once the reservations in these basins are fully allocated. Ecology is proposing the closures in the rule proposal based on two factors.

First, the Washington Department of Fish and Wildlife has recommended and reaffirmed denial or limitations on withdrawals from several Skagit tributaries under the RCW 77.55.050 (WDFW 2005). These streams are listed on Ecology's Surface Water Source Limitation (SWSL) list (Table 5). In addition, habitat studies (IFIM and Toe-width) completed in other western Washington small streams have consistently shown that surface water is generally not available much of the year (often 50% or more of the year) if flows are to be maintained at levels protective of fish. In the judgment of Ecology biologists in consultation with Fish and Wildlife, it is unlikely that the identified Skagit River tributaries could maintain flows protective of fish resources while also supporting reliable water supply for most purposes. The exception to this determination is the use of the reservation discussed previously.

Second, closing these tributaries to consumptive water uses is one of the actions taken to minimize the potential additional impacts on streams. The basin closures will automatically be effective once Ecology determines that the reserved quantities in the particular sub-basin have been fully allocated. Ecology will notify the public of the effective closures through publication of a notice in a regional newspaper. The stream closures are consistent with the OCPI finding that water use for out-of-stream purposes should be the smallest amount practicable. The closure will limit future water uses in these basins to: uses authorized in the reservation; nonconsumptive water uses; uses where the impacts to surface water are fully mitigated; or uses of ground water that will not impact the stream. Over time, this may result in fewer total water withdrawals in a closed basin.

Table 4 –Sub-basins Subject to Closure

Alder Creek	Cumberland Creek	Morgan Creek
Anderson / Parker / Sorenson Creeks	Day Creek	Muddy Creek
Careys Creek	Fisher Creek	Nookachamps Creek – East Fork
Carpenter Creek	Gilligan Creek	Nookachamps Creek – Upper
Childs / Tank Creeks	Grandy Creek	O'Toole Creek
Coal Creek	Hansen Creek	Red Cabin Creek
	Jones Creek	Salmon/Stevens Creeks
	Loretta Creek	Wiseman Creek
	Mannser Creek	

Table 5 – SWSL Streams

Surface Water Source Name	**Location Section-Township-Range**	**WDFW Recommended SWSL**	**SWSL Date 1**	**SWSL Date 2**	**Comment** or **Description**
Carpenter Creek		Low Flow	04/11/ 1975		
Cool Creek		Low Flow	05/09/ 1956		
Jones Creek	09-36-06E	Low Flow	11/20/ 1950		5 cfs
Nookachamps Creek	04-34-04E	Denial	11/13/ 1944	04/15/ 1992	
Diosbud Creek	32-16-11E	Denial	09/28/ 1961		
Grandy Creek	15-35-07E	Low Flow	12/06/ 1949		6 cfs
Unnamed Stream tributary to Sauk River (#0563)	02-34-09E	Low Flow	0/29/5 4		1 cfs

HYDRAULIC CONTINUITY

In the proposed Skagit instream flow rule amendment Ecology finds that, based on knowledge of the hydrogeology of the basin, and the location and depth where ground water withdrawals generally occur, future ground water withdrawals may capture water that would result in impacts to surface water flows and levels in the Skagit River basin. Impacting surface water may impair the existing instream flow or reduce flows in the sub-basins proposed for closure. This leads to a clarification in the rule that a ground water permit may only be approved if an applicant can demonstrate, through additional studies and technical analysis, and to the satisfaction of the department, that the proposed use will not cause impairment to existing water rights, including the instream flows, or in the case of a closed basin, the withdrawal would not consume water for a legally closed source.

Ecology considers this rule language to be a clarification of existing law and policy. A determination that a new water right will not cause impairment of a senior water right, including an instream flow, is a strict test. The fact that there may be any impairment of an instream flow from a groundwater withdrawal is cause for denial or conditioning of a water right. This is not a matter of degree. Impacts that may cause an instream flow violation or exacerbate one constitutes impairment. This policy has been affirmed by the courts in *Postema v. PCHB*, 142 Wn.2d 68 (2000). Given this existing high legal standard, Ecology must be very conservative in reviewing water rights for potential impairment of instream flows.

Technically, Ecology's finding that there may be hydraulic continuity between surface and ground water in the Skagit basin is based on a general knowledge of the hydrogeology of the Puget Sound region and the Skagit basin. The hydrogeology of the basin is described in USGS Water Supply Bulletin 47, entitled *Water in the Skagit River Basin, Washington* (USGS 1978). In this region ground water is generally recharged by precipitation and snowmelt. After entering the ground this water flows through aquifers and aquitards, driven by differences in water level elevations and physical properties of the subsurface, to eventually discharge into a surface water body (such as streams, rivers, lakes, and marine waters). Pumping a well alters the natural ground water flow gradients and directions around the well. This can cause there to be less discharge to a surface water body or can cause water to be drawn from a surface water body into the ground. A significant portion of stream flow in the basin is dependent on base flow (ground water discharge), especially in the late summer months in tributary sub-basins. Sinclair and Pitz (1999) estimated that base flow represents 40-90% of stream flow during the summer months. For instance, base flow was estimated to represent 91-98% of stream flow in Alder Creek, 44-66% of stream flow in Day Creek, 55-72% of stream flow during July- September (Sinclair and Pitz 1999). Consequently, capturing and consuming groundwater as it flows downward or reemerges likely impacts stream flows and may cause impairment. Several studies, including the USGS report *Numerical model analysis of the effects of ground-water withdrawals on discharge to streams and springs in small basins typical of the Puget Sound Lowland, Washington* (USGS 1999) support this finding.

However, ground and surface water interaction is inherently complex, as it is difficult to determine the quantity and movement of groundwater and the degree of interaction with surface water. Ecology acknowledges that additional future scientific investigations of the hydrogeology of the Skagit River basin may identify areas where water may be used without impairing the instream flows set in this chapter. If future scientifically sound investigations identify such areas, the department will notify the public of these finings through publication of a *Skagit River Water Supply Bulletin.*

REFERENCES

Ecology 2005. *Preliminary Benefit-Cost & Least Burdensome Analysis for Amendment to Chapter 173-503 WAC Instream Resources Protection Program-Lower and Upper Skagit Water Resources Inventory Area (WRIA 3 AND 4)*. February, 2005. Washington State Department of Ecology. Lacey, Washington.

EES 2002. *Skagit River Basin; Return Flows to Aquifer - Exempt Wells*. Draft Memorandum. Dave Moldal, Economic and Engineering Services, Inc. Olympia, Washington. December 10, 2002

Greenberg 2005. *Current and Projected Future Water Demands for Skagit County's Domestic, Commercial, and Industrial Sectors*. HydroLogic Services Company, Bellingham, Washington. March 2005.

Greenberg 2005b. Memorandum Addendum 1, September 2005 *Comparison of Future Water Demand under three Population Forecasts, Population Distribution for Ecology's SEPA Analysis and Estimated Future Agricultural Distribution.* HydroLogic Services Company. Bellingham, Washington. September 22, 2005.

Greenberg 2005c. *Current and Projected Future Water Demands for Skagit County's Irrigated Agriculture.* Hydrologic Services Company. Bellingham, Washington. March 2005.

HDR 2005. *Section 2 Drainage and Irrigation Operations, Facilities and Needs.* Draft Report to Skagit Comprehensive Irrigation Management Plan (CIDMP). HDR. Mount Vernon, WA. July 28, 2005.

Sinclair, Kirk and Charles Pitz. 1999. *Estimated Baseflow Characteristics of Selected Washington Rivers and Streams. Water Supply Bulletin No. 60. Publication No. 99-327.* October 1999. Washington State Department of Ecology. Olympia, Washington.

Skagit County 2003. *Upper Skagit Watershed Development Activities/Potential Summary: Draft - - May 20, 2003.* May 20, 2003. Skagit County, Washington.

Skagit County 2004a. Draft map of potentially affected parcels. June 29, 2004. Skagit County, Washington.

Skagit County 2004b. Draft map of Skagit tributary basins. Map files sent via personal Communication. Kim Berry, Skagit County GIS. December 2, 2004. Skagit County, Washington.

US Census 2000. *Profile of General Demographic Characteristics: 2000* - - *Geographic area: Skagit County, Washington*. US Census Bureau.

USGS 1978. *Water in the Skagit River Basin, Washington. Water-Supply Bulletin 47.* Drost, B.W. and R.E. Lombard. Washington Department of Ecology (prepared in cooperation with the U.S. Geological Survey). Lacey, Washington

USGS 1999. *Numerical model analysis of the effects of ground-water withdrawals on discharge to streams and springs in small basins typical of the Puget Sound Lowland, Washington*. Morgan, D.S., and Jones, J.L. U.S. Geological Survey Water-Supply Paper 2492.

USGS 2004. *Estimated Domestic, Irrigation, and Industrial Water Use in Washington, 2000*. Lane, R.C. U.S. Geological Survey Science Investigations Report 2004-5015

WDFW 2005. Personal Communication. Letter from Hal Beecher, Instream Flow Biologist, Washington Department of Fish and Wildlife. January 20, 2005. Olympia, Washington.

WDOH 2004. *Timely and Reasonable Guidelines* (Draft 12/22/04). December 22, 2004. Washington Department of Health, Drinking Water Program. Olympia, Washington.

ATTACHMENT 1

Suggested protocols for estimating low stream flows for ungauged sub-basins in the lower Skagit watershed

Martin Walther, P.E., Hydrology/Hydraulics Specialist
Water Resources Program / Dam Safety Office
December 23, 2004

The basic approach suggested here for estimating low stream flows at ungauged locations is to identify a surrogate watershed for which stream flow data are available and for which statistical analyses have been (or can be) done, then to scale those flow estimates from the gauged watershed to the ungauged watershed.

The basic premise of this approach is that flow data for a gauged watershed are representative of the hydrologic processes at work in nearby, similar, ungauged watersheds. The two most important parameters for determining stream flows are drainage area and precipitation, with mean annual precipitation being the rainfall parameter for which data are most readily available. The U.S. Geological Survey has used this approach in their statistical regression analysis of high flows for various water resource regions in Washington State.

Low flows are considered to represent groundwater runoff, or base flow, that occurs some time after the last significant precipitation and surface runoff have occurred. Watershed geology is an important parameter here, particularly with regard to similarity between a gauged watershed with flow data and an ungauged watershed for which flow estimates are needed. Watershed soils and land uses may also be significant factors for watershed similarity.

Watersheds with long-term records

Four watersheds with long-terms stream gauge records and flow statistics computed by the USGS are located in or near the lower Skagit watershed. The specific streams are Alder Creek, located on the northeast side of the project area; Day Creek, located on the south side of the project area; East Fork Nookachamps Creek near Big Lake (3.56 sq.mile drainage area), on the west side of the project area; and Pilchuck Creek, located just south of the Nookachamps Creek and Day Creek watersheds, within the Stillaguamish River basin. Ecology's Environmental Assessment Program elected to use flow data from the Pilchuck Creek gauge to estimate 7-day, 10-year low flows for several lower Skagit tributaries in their TMDL study. Some flow data and statistics are listed on pages 2 and 3, and also on a separate spreadsheet.

Watersheds with short-term records

Two additional watersheds with short-term stream gauge records are located in the lower Skagit watershed. The specific streams are Wiseman Creek, located on the north side of the project area; and East Fork Nookachamps Creek near Clear Lake (20.5 sq.mile drainage area), on the west side of the project area. Some flow data and statistics are listed on page 4, and also on a separate spreadsheet.

Alder Creek near Hamilton (NE side of project area)

Record	28 years, 1943 to 1971
Drainage area	10.7 sq. miles
Precipitation	58 inches (per USGS report)
Geology	Outwash; till; rock
Avg. stream flow	38 cfs
Avg. stream flow	3.6 CSM (CSM = cfs/sq.mile)
Avg. runoff (total)	48 inches (calculated from stream flow)
Avg. base flow	31 cfs
Avg. base flow	2.9 CSM
Avg. base flow	82 % of total stream flow
7-day record median	8.2 cfs
ratio min./median	66 %
7-day record min.	5.4 cfs
7-day record min.	0.50 CSM
7-day 10-yr flow	6.3 cfs
7-day 10-yr flow	0.59 CSM
7-day 10-yr flow	10.2×10^{-3} CSM/inch

Day Creek near Lyman (south side of project area)

Record	18 years, 1943 to 1961
Drainage area	34.2 sq. miles
Precipitation	77 inches (per USGS report)
Geology	Rock; slide deposits; outwash and till
Avg. stream flow	280 cfs
Avg. stream flow	8.2 CSM
Avg. runoff (total)	111 inches (calculated from stream flow)
Avg. base flow	150 cfs
Avg. base flow	4.4 CSM
Avg. base flow	54 % of total stream flow
7-day record median	15 cfs
ratio min./median	54 %
7-day record min.	8.1 cfs
7-day record min.	0.24 CSM
7-day 10-yr flow	9.9 cfs
7-day 10-yr flow	0.29 CSM
7-day 10-yr flow	2.6×10^{-3} CSM/inch

East Fork Nookachamps Creek (west side of project area)

Record	9 years, 1962 to 1971
Drainage area	3.56 sq. miles
Precipitation	60 inches (per USGS report)
Geology	Rock; till
Avg. stream flow	22 cfs
Avg. stream flow	6.2 CSM
Avg. runoff (total)	84 inches (calculated from stream flow)
Avg. base flow	14 cfs
Avg. base flow	3.9 CSM
Avg. base flow	64 % of total stream flow
7-day record median	1.3 cfs
ratio min./median	27 %
7-day record min.	0.35 cfs
7-day record min.	0.098 CSM
7-day 10-yr flow	0.4 cfs
7-day 10-yr flow	0.112 CSM
7-day 10-yr flow	1.34×10^{-3} CSM/inch

Pilchuck Creek (southwest of project area)

Record	26 years, 1929 to 1931, 1950 to 1975
Drainage area	52.0 sq. miles
Precipitation	64 inches (per USGS report)
Geology	Rock; till
Avg. stream flow	279 cfs
Avg. stream flow	5.4 CSM
Avg. runoff (total)	73 inches (calculated from stream flow)
Avg. base flow	151 cfs
Avg. base flow	2.9 CSM
Avg. base flow	54 % of total stream flow
7-day record median	4.7 cfs
ratio min./median	12 %
7-day record min.	0.56 cfs
7-day record min.	0.011 CSM
7-day 10-yr flow	1.9 cfs
7-day 10-yr flow	0.037 CSM
7-day 10-yr flow	0.50×10^{-3} CSM/inch

Wiseman Creek near Lyman (north side of project area)

Record	8 years, 1974 to 1983
Drainage area	3 sq. miles (approx.)
Geology	Rock; outwash; lahar deposits
Avg. stream flow	13 cfs
Avg. stream flow	4.3 CSM
Avg. runoff (total)	59 inches (calculated from stream flow)
Avg. base flow	9.3 cfs
Avg. base flow	3.1 CSM
Avg. base flow	72 % of total stream flow
7-day record median	0.92 cfs
ratio min./median	78 %
7-day record min.	0.72 cfs
7-day record min.	0.24 CSM

East Fork Nookachamps Creek (west side of project area)

Record	8 years, 1943 to 1950 and 1962 to 1963
Drainage area	20.5 sq. miles
Geology	Rock; till; slide deposits; alluvium
Avg. stream flow	86 cfs
Avg. stream flow	4.2 CSM
Avg. runoff (total)	57 inches (calculated from stream flow)
Avg. base flow	46 cfs
Avg. base flow	2.2 CSM
Avg. base flow	53 % of total stream flow
7-day record median	2.5 cfs
ratio min./median	33 %
7-day record min.	0.83 cfs
7-day record min.	0.040 CSM

Hydrology Critique

Within the project area, there appear to be three relatively distinct hydrologic areas. The first is the north side of the Skagit River. The Alder Creek watershed and long-term stream gauge are located in this hydrologic area near the east end, and the Wiseman Creek watershed and short-term stream gauge are located near the west end. The second area is the south side of the Skagit east of Cultus Mountain. The Day Creek watershed and long-term stream gauge are located in this hydrologic area.

The third area is the Nookachamps Creek watershed and the other sub-basins at the west end of the project area. The East Fork Nookachamps Creek stream gauges are located within this hydrologic area. The Pilchuck Creek stream gauge is located just south of this hydrologic area, and was used by the EAP Program to estimate low flows for several sub-basins in this area in their TMDL study, apparently due to its longer period of record for computing flow statistics.

North sub-basins. For the 7-day low flows, Alder Creek has highest CSM value (cfs/sq.mile) of the three hydrologic areas. This observation is consistent with the very high percentage of base flow as a percentage of total stream flow. A high percentage of the Alder Creek watershed is underlain by unconsolidated sediments (both outwash and till), which apparently contributes to relatively high groundwater storage that is released gradually during low flow periods. It is noteworthy that the ratios of low flows to average flows are higher for Alder Creek than for the other long-term stream gauges.

Short-term flow data for Wiseman Creek show a slightly smaller percentage of base flow than Alder Creek, apparently due to a higher portion of the watershed underlain by rock, although still higher than for the two other hydrologic areas. The flow data for Wiseman Creek also show relatively high ratios of low flows to average flows (especially for 7-day flows), although 7-day flows per unit drainage area (CSM values) are somewhat lower than for Alder Creek. This observation of high base flows and high ratios for low vs. average flows in both of the gauged basins supports a conclusion of similarity among the north-side sub-basins. Considering the lower CSM value for 7-day record flows in Wiseman Creek, it seems appropriate to use a lower CSM value for north-side sub-basins at the west end for flow estimating purposes.

From this critique, it appears that the hydrologic processes in the Alder Creek watershed are reasonably representative of those for the other north-side sub-basins (with appropriate scaling for the west-end sub-basins). With basin-specific precipitation estimates available from the GIS system, scaling flow estimates based on precipitation for each sub-basin is also recommended.

South sub-basins. For the 7-day low flows, Day Creek has a significantly smaller CSM value than Alder Creek to the north. This observation is consistent with the much smaller percentage of base flow as a percentage of total stream flow for Day Creek. A high percentage of the Day Creek watershed is underlain by rock, which typically does not provide much groundwater storage, and by slide deposits, which apparently release their infiltrated groundwater quickly rather than retain groundwater in storage for gradual release during low flow periods. As compared to Alder Creek, the ratios of low flows to average flows are lower for Day Creek, which is consistent with the characterization of less groundwater storage within the Day Creek watershed available for delayed release.

It is interesting to note that the orographic effects of Cultus Mountain and other higher elevations south of the Skagit valley do show up in the significantly higher mean annual precipitation of the Day Creek basin and nearby sub-basins as compared to Alder Creek and the other sub-basins on the north side of the valley, and also in higher CSM values for runoff per unit drainage area for the Day Creek basin.

The other south-side sub-basins are located in reasonably close proximity to the Day Creek watershed, and appear to have similar geology and precipitation. From this critique, it appears that the hydrologic processes in the Day Creek watershed are reasonably representative of those for the other south-side sub-basins. With basin-specific precipitation estimates available from the GIS system, scaling the flow estimates based on the precipitation for each sub-basin is also recommended.

West sub-basins. For the 7-day low flows, Nookachamps Creek has a significantly smaller CSM value than either Alder Creek or Day Creek. This observation is consistent with the smaller percentage of base flow as a percentage of total stream flow for Nookachamps Creek. The small East Fork watershed with the long-term stream gauge has a much steeper basin slope than either Alder Creek or Day Creek. Also, a high percentage of the Nookachamps Creek watershed is underlain by rock, which typically does not provide much groundwater storage, and by till, where the steep basin slope apparently encourages more surface runoff and discourages infiltration into the underlying groundwater system. As compared to Alder Creek, the ratios of low flows to average flows are lower for Nookachamps Creek, which is consistent with the characterization of less groundwater storage within the Nookachamps Creek watershed available for delayed release.

Short-term flow data for the larger Nookachamps Creek watershed show similar trends as the flow data for the smaller, upstream watershed, although with smaller CSM values and a smaller percentage of base flow as compared to total stream flow. The differences are probably due, at least in part, to lower basin-average precipitation and corresponding runoff per unit area for the larger, downstream watershed as compared to the smaller, upstream watershed. It seems clear that the hydrologic processes in the Nookachamps watershed do yield less groundwater runoff and lower 7-day CSM values than for the Alder Creek and Day Creek basins. Considering the lower CSM value for 7-day record flows in the larger Nookachamps watershed, it seems appropriate to use a lower CSM value (scaled down from the value for the long-term gauge) for flow estimating purposes.

The other west-side sub-basins are located in the same basin or in reasonably close proximity to the Nookachamps Creek watershed, and appear to have similar geology and precipitation. From this critique, it appears that the hydrologic processes in the Nookachamps Creek watershed are adequately representative of those for the other west-side sub-basins, so the scaled-down low-flow CSM value for Nookachamps Creek may be used to estimate low flows in the other west sub-basins. With basin-specific precipitation estimates available from the GIS system, scaling flow estimates based on precipitation for each sub-basin is also recommended.

As mentioned above, the Pilchuck Creek stream gauge is located just south of the Nookachamps Creek watershed, and was used by the EAP Program to estimate low flows for several sub-basins in this area in their TMDL study, apparently due to its longer period of record for computing flow statistics. Flow data for the Pilchuck Creek watershed show similar trends as the flow data for the Nookachamps Creek watershed, although with smaller CSM values for 7-day flows and lower ratios of low flows to average flows. When the flow statistics for the smaller, upstream Nookachamps Creek gauge are scaled to the larger Nookachamps Creek watershed, the resulting CSM values are similar to those for the Pilchuck Creek watershed. This provides some additional confidence that the Nookachamps Creek gauge data are representative of longer-term trends and extrapolations.

Computation procedures

As discussed above, the long-term flow data for Alder Creek, Day Creek and Nookachamps Creek each appear to be adequately representative of the hydrologic processes occurring in their respective hydrologic areas with regard to low stream flows. The other sub-basins within each area appear to have similar geology and precipitation, so that the CSM values may be used directly, or scaled as appropriate, to estimate low flow values for the ungauged sub-basins.

The flow computations proceed generally as follows. After the drainage area for each sub-basin has been determined, simply multiply the drainage area (in square miles) by the applicable CSM value. For this project, the respective drainage areas are estimated from GIS data for the project area. The specific computations are done using a spreadsheet and shown separately.

Precipitation estimates for each sub-basin are also available from the GIS data. From a comparison of these precipitation estimates with the runoff values for the stream gauges, it appears that there may be some significant differences in precipitation between the sub-basins and the stream gauge data, and also between sub-basins within each hydrology area. For the computations to consider these differences in precipitation, the CSM values for the three long-term flow gauges need to be converted to CSM/inch values, as listed above. In addition to the drainage area, the precipitation for each sub-basin must also be factored into the calculations. Low flow values for each sub-basin are computed by multiplying the drainage area (square miles) times the precipitation (inches) times the applicable CSM/inch value. The specific computations are done using a spreadsheet and shown separately. In my opinion, this approach provides a better estimate of low flows than the simplified approach based on drainage area only.

I have tentatively presumed that the 10-year recurrence interval is the desired probability and frequency of low flow occurrence. “10-year” flows have a 1 in 10 chance of occurring in any one year, and about a 6 in 10 chance of occurring at least once in any 10 year period. The USGS literature includes computed flow values for other recurrence intervals (ranging from 2 years to 100 years) and also for other flow durations (3-day flows, for example), so CSM values may be easily computed for almost any desired flow duration and recurrence interval. It should be noted that the 7-day 10-year low flow is commonly selected as being representative of conditions that are drier than average but not extreme drought.

ATTACHMENT 2
Addendum to Suggested protocols for estimating low stream flows for ungauged sub-basins in the lower Skagit watershed

DEPARTMENT OF ECOLOGY
Water Resources Program / Dam Safety Office

April 27, 2005

To: File for Record / Geoff Tallent, Skagit Watershed Lead

From: Marty Walther, Hydrology/Hydraulics Engineer

Subject: Response to comments on low-flow computations
March 22, 2005 letter from Geomatrix Consultants to Mentor Law Group

Here are my tentative responses to the Comments on Attachment 1 from Geomatrix Consultants, found on pages 8 through 13 of the March 22, 2005 letter from Geomatrix Consultants to Mentor Law Group. (Aside: The first page of Geomatrix' comment letter is dated March 18, but there is a reference to a personal communication dated March 19 at the bottom of the page, and following pages are all dated March 22, so I presume March 22 is the correct date for the letter.)

I appreciate Geomatrix' thoughtful critique of my analysis, and I agree with many of their comments. I did not see any issues in their comments that would prompt me to revise my conceptual approach or computation procedures. I would like to revise some basin-specific calculations in light of new rainfall information they presented.

My original analysis is summarized in three documents:

- Suggested protocols for estimating low stream flows for ungauged sub-basins in the lower Skagit watershed. Text document, 9 pages.
- Stream gauge data and flow statistics for gauged basins in and near the lower Skagit watershed. Spreadsheet, 4 pages.
- Estimated low stream flows for ungauged sub-basins in the lower Skagit watershed. Spreadsheet, 4 pages in 2 worksheets.

Some of Geomatrix' comments suggest that they may not have had convenient access to all three of these documents. The flow data and statistics summarized on pages 2, 3 and 4 of the suggested protocols are presented in more detail in the spreadsheet of stream gauge data and flow statistics.

In light of the new rainfall information Geomatrix called to our attention, I have tentatively revised the spreadsheets for stream gauge data and flow statistics and for the estimated low stream flows for ungauged sub-basins. Changes to the stream gauge data and flow statistics spreadsheet were made within the existing 4-page format. Changes to the estimated low stream flows spread-sheet include adding 2 new worksheets, each 2 pages long, to compare my original precipitation values with the new precipitation values they calculated along with some new values we were able to obtain, and revising the stream flow calculations in the second worksheet (calculation by drainage area and precipitation) for the sub-basins in the West and South areas. This spreadsheet is now 8 pages long in 4 worksheets.

My tentative responses to Geomatrix' specific comments follow below, in the order presented in their letter on pages 8 through 13.

Comments on Attachment 1

Comments on Hydrologic Assumptions

1. ***No basis for using 7Q10. 7Q10 is an extreme event.***

Selecting the specific recurrence interval and flow duration is really a policy decision, not an engineering decision. There is some precedent from wastewater engineering for using 7Q10 as being representative of low stream flow conditions (for example, see Ecology's *Criteria for Sewage Works Design*, page G1-22), and our decision-makers have tentatively accepted my recommendation on this issue, but the flow calculations can be easily revised to another recurrence interval such as 5 years or 2 years, or to another flow duration such as 30 days.

I interpret the 7-day, 10-year low flow as being representative of a longer dry spell, with a critical one-week period embedded within the longer event. The overall event has a 1 in 10 probability of occurring in any one year. I agree that one week out of ten years (520 weeks) is only 0.2 percent of the time, but that one week period would not occur in isolation. The overall event would take weeks or months to develop, and the economic and environmental impacts of the dry spell would last much longer than just the 7-day critical period.

I'm not aware that hydrologists generally consider a 10-year event to be an extreme event. For WSDOT roadway drainage facilities, the smallest design storm they use is the 10-year event (see WSDOT's *Hydraulics Manual*, page 1-6). The peak flows from their design storms may be just a few hours in duration, often less than a day, and then recede to less harmful levels. A one day period out of ten years (3652 or 3653 days) is only 0.03 percent of the time, but similarly, the economic impacts could last much longer than the actual storm duration. The probability of the hydrologic event occurring within any particular year is usually more concern than the specific flow duration.

As I said, selecting the specific recurrence interval and flow duration is really a policy decision for others with that authority to make. Whatever they decide, the flow calculations can be easily revised to another recurrence interval or to another flow duration.

2. *Stream gages with more than 10 years of data are preferable.*

I agree. Also, more recent data would have been desirable. Of the six gauges, five have data that are more than 30 years old and the other one has data that are more than 20 years old. I considered all the flow data I could find. This was it for the long term flow data.

3. *Basin area, geometry and hydrogeology are more important than precipitation in determining low flows.*

In my opinion, precipitation should be considered in conjunction with watershed area and underlying geology in estimating low flows in the ungauged watersheds. In my analysis, drainage area and precipitation were factored explicitly into the calculations. Geology was considered in the selection of which gauged watershed to use as a surrogate for each ungauged sub-basin. With regard to geology, I considered the hydraulic properties of the geologic materials to be hydrologically more significant than the geologic origin of the materials. For example, low-permeability glacial till was considered to be more similar to low-permeability rock than to high-permeability glacial outwash. I also felt that close proximity between the gauged and ungauged watersheds was preferable to a surrogate watershed located some distance away from the ungauged sub-basin.

In my conceptual model of the lower Skagit sub-basins, recharge to the groundwater system would generally occur during the winter months of high precipitation and saturated soils, and the underlying geology would hold onto the recharged groundwater for gradual release to the stream later on in the summer months. On a relative scale, high base flows would be due to a combination of high precipitation, high infiltration and deep percolation capacity, and high groundwater storage capacity. Low base flows could be due to low precipitation, to low infiltration or percolation capacity, or to low storage capacity.

In fact, the effects of precipitation do show up in the base flow statistics. The Day Creek watershed has three times the drainage area but five times the base flow of the Alder Creek watershed just across the river. Base flow (interpreted as groundwater runoff) accounts for 82 percent of the total runoff in Alder Creek, a high percentage that is consistent with the glacial outwash geology of the Alder Creek watershed where high infiltration and high groundwater storage would be expected.

By comparison, base flow accounts for 54 percent of the total runoff in Day Creek, a lower percentage that is consistent with the rock and landslide geology of the Day Creek watershed. Low infiltration and low groundwater storage would be expected in the rock areas of the Day Creek watershed, while high flow-through with low groundwater storage would be expected in the slide areas of the watershed. The relatively higher value (per unit drainage area) for groundwater runoff in Day Creek is explained by the higher precipitation in the Day Creek watershed as compared to Alder Creek.

While I agree with the Maine study that watershed geology is a key factor for low stream flows, I believe Maine has a more uniform distribution of precipitation across the state and a more uniform distribution of monthly rainfall during the year than does Washington. This may explain why the Maine study found precipitation to be less of a factor for low stream flows in that state than watershed area or underlying geology. My analysis considered all three of these factors.

4. ***Discrepancies in precipitation values between PRISM and the USGS reports.***

I agree. As discussed below for comment 6, there is a similar discrepancy within the USGS report for measured runoff as compared to reported precipitation.

The actual discrepancy is between the PRISM precipitation data for 1961 to 1990 compared to the U.S. Weather Bureau (National Weather Service) precipitation map for 1930 to 1957. The USGS obtained their precipitation values from the NWS map. The magnitude of the differences between the PRISM data and the NWS map is too large to be explained by the different periods of record. At this time, I am still researching this issue.

5. ***Discrepancies in flow values between USGS reports and Ecology's base flow study.***

I agree, although I considered the differences to be relatively small, not large enough to significantly affect the conclusions of my analysis. The USGS calculated the actual mean values for the entire record. Ecology's base flow study calculated the mean values for each year, then reported the median, maximum and minimum values of the annual means. The largest difference between the USGS actual means and Ecology median of annual means is about 8 percent. Since I wanted to make a comparison to the values for measured 7-day low flows and for measured base flows, I elected to use a value representing average flows from the same document. The comparison of average flows to base flows and low flows was used primarily to illustrate the effects of geology and precipitation on low flows, as described in the suggested protocols paper.

6. ***Runoff depths more than reported precipitation in several gauged basins.*** (Aside: I presume the comment of runoff <u>less</u> than precipitation was a typo.)

I agree. I noticed this situation for the Day Creek, Pilchuck Creek and upstream East Fork Nookachamps Creek gauges. In my initial calculations for each of these cases, I presumed that the measured runoff values were accurate, that the reported precipitation values were probably in error, and that the measured runoff (converted to inches) was a more accurate estimate of the precipitation that actually occurred on the watershed. This is shown more clearly in my spreadsheet showing the stream gauge data and flow statistics. My approach here did not include an allowance for evapotranspiration, so would underestimate the actual precipitation that occurred, but provided a closer estimate of the actual precipitation than the values listed in the USGS reports.

In my conceptual model of the lower Skagit sub-basins, some of the groundwater recharge will re-emerge as base flow later in the summer, so does get measured by the stream gauge, but I agree that there would be some water lost to evapotranspiration. In the Alder Creek watershed, if we presume that the listed precipitation value is accurate, evapotranspiration would account for the 10 inch difference between precipitation and runoff. For the Day

Creek, Pilchuck Creek and upstream East Fork Nookachamps Creek gauges, I tentatively elected to not make any further revisions to the precipitation values other than to increase them to at least account for all the runoff.
For the two short-term gauges, I was primarily interested in the comparisons of base flows and low flows to average flows. The precipitation values for these two watersheds were not used in the calculations and were not listed in the suggested protocols paper. Precipitation values for these gauges are listed on the spreadsheet for stream gauge data and flow statistics.

The rainfall values from the PRISM system provide new information about the hydrology in the lower Skagit sub-basins and are more consistent with the runoff measured by the USGS. Revisions to my low flow calculations are discussed below in item 8.

7. ***CSM/inch value for Day Creek used inches of runoff rather than reported precipitation*.**

This is a correct observation. This is shown more clearly in the spreadsheet for stream gauge data and flow statistics. As mentioned in item 6, I considered the measured runoff to be a more accurate measure of actual precipitation for those gauges where the listed precipitation was less than the measured runoff. Revisions to the calculations are discussed in item 8.

8. ***Sub-basin precipitation values were taken from an old precipitation map rather than more recent data*.**

This is a correct observation, although it was not my original intent. In light of the new rainfall information submitted by Geomatrix, I have tentatively revised my flow calculations for the South and West sub-basins.

As described in the suggested protocols paper in the discussion of computation procedures, precipitation estimates for each sub-basin were taken from the GIS data in Ecology's GIS system. I had presumed that our computerized GIS system would use the most recent precipitation data from a source such as PRISM. Geomatrix' comment prompted a deeper investigation as to the source of the precipitation data in our GIS system, which turned out to be a digitized version of the 1965 NWS precipitation map. My thanks to Geomatrix for catching this and calling it to my attention. This incident illustrates the importance of peer review in scientific topics such as this one.

The discrepancy in the USGS report between measured runoff and reported precipitation for several stream gauges was mentioned above in item 6. There is much better agreement between the PRISM rainfall values and the USGS runoff, which tends to support the PRISM values as being more accurate than the previous peer-reviewed and formally published NWS precipitation values. As noted above in item 4, I am still researching this issue.

Comparing the PRISM rainfall values with the values used in my original analysis, there are larger differences for the higher elevations with higher precipitation. For this situation, we would expect the highest rainfall differences to occur in the higher-elevation South side sub-basins. Comparisons of precipitation by sub-basin for PRISM rainfall values compared to the original calculation showed an 18 percent difference for the West sub-basins, a 56 percent difference for the South sub-basins, and a 0.9 percent difference for the North sub-basins.

In light of the new rainfall information presented by Geomatrix, my low-flow estimates are tentatively revised as follows. Since the PRISM rainfall values for the North sub-basins are substantially the same as my original analysis, I have not made any changes to the flow calculations for the North sub-basins. For the West sub-basins, the higher PRISM precipitation values per Geomatrix' calculations and precipitation map have been used in the revised flow calculations. The CSM/inch value for the West side sub-basins was already computed using the measured runoff value of 84 inches (as compared to the reported rainfall of 60 inches) for the upstream East Fork Nookachamps Creek gauge, so did not need any adjustment in light of the PRISM rainfall data from Geomatrix. The large grid for the PRISM precipitation values appears to have resulted in a very large precipitation value for upstream East Fork Nooka-champs Creek. In the absence of other corroborating evidence, I did not consider Geomatrix' listed rainfall value of 140 inches for the upstream East Fork Nookachamps Creek watershed to be accurate.

For the South sub-basins, the higher PRISM precipitation values per Geomatrix' calculations and precipitation map have been used in the revised flow calculations, with the following modifications. The large grid for the PRISM precipitation values appears to have resulted in very large precipitation values for Gilligan, Cumberland, and O'Toole Creeks. My original calculations show similar precipitation for these three sub-basins as compared to Day Creek. Day Creek precipitation of 114 inches is verified by the USGS runoff value of 111 inches. In the absence of other corroborating evidence, I am reluctant to use higher precipitation values for Gilligan, Cumberland, O'Toole Creeks than for Day Creek, so I used the Day Creek value of 114 inches for these three sub-basins rather than Geomatrix' listed rainfall values. The spreadsheet for estimated stream flows has been revised to calculate low flows based on these precipitation estimates.

9. ***Apparent use of USGS peak flow methodology, improper application to low flows*****.**

The USGS peak flow report was cited as a precedent to use drainage area and precipitation as factors in calculating flows in ungauged watersheds. (I am aware that the USGS has done studies of low flows in other states, such as the Maine study cited by Geomatrix, but here in Washington we have only the high flow studies at this time.) This citation was not intended nor used to imply that other factors, such as geology, need not be considered. As stated in several items above, my analysis considered drainage area, geology and precipitation, all in conjunction with each other.

Geology was the primary factor used to pair each ungauged sub-basin with the appropriate surrogate gauged watershed. Geologic parameters such as permeability, hydraulic conductivity and transmissivity were not explicitly quantified; however, my sense is that these parameters are all reflected in the ratio of base flow (interpreted as groundwater runoff) to average stream flow (interpreted as total runoff of groundwater and direct surface flow). As described in my suggested protocols paper and also reflected in the stream gauge data and flow statistics spreadsheet, my hydrology critique for all three areas (north, south and west sub-basins) attempted to explain the observed flow regimes in light of the underlying watershed geology.

10. ***Unsubstantiated assertion of hydrologic similarity between gauged and ungauged basins*.**

I disagree. This comment seems to derive primarily from Geomatrix' contention that watershed geology was not considered, or was not adequately considered, in my analysis. As noted in several responses above, geology was considered in explaining the observed flow regimes in each of the gauged watersheds and in selecting the appropriate surrogate gauged watershed for each sub-basin. Whether this was adequate would be a matter of professional opinion.

Extrapolation of Geologic Conditions

11. ***Sub-basin geology not adequately considered*.**

I disagree. As noted in several responses above, geology was considered in explaining the observed flow regimes in each of the gauged watersheds and also in selecting the appropriate surrogate gauged watershed for each sub-basin. Whether this was adequately done would be a matter of professional opinion.

I agree completely with the importance of geology as a key factor in understanding the flow regime of a stream, especially for base flows and low flows. I also agree with Geomatrix' characterization of the difference in flow regimes that would be expected between a watershed with a shallow aquifer system as compared to a watershed underlain by bedrock

12. ***Scaled-down CSM and CSM/inch values for Nookachamps Creek not explained*.**

The detailed calculations are shown on the spreadsheet for stream gauge data and flow statistics. I would agree that the scaled values are mentioned but not explained within the suggested protocols document.

For Nookachamps Creek, I felt that the East Fork downstream gauge was more representative of the hydrologic processes operating in the overall watershed. Unfortunately, the East Fork upstream gauge has the published statistics for the 7-day, 10-year low flow (and other recurrence intervals and flow durations). I scaled the upstream CSM and CSM/inch 7Q10 values by the ratio of the 7-day record minimum CSM values (from the base flow report) for the downstream and upstream gauges to derive my estimate of the CSM and CSM/inch values to use to calculate 7Q10's for the ungauged locations within the Nookachamps watershed and for the other west side sub-basins.

13. *Fisher Creek geology is strong contrast to Nookachamps or Carpenter Creeks*.

My assessment is that the hydrogeologic information for Fisher Creek is not definitive on this score. Charles Pitz and Robert Garrigues of Ecology's Environmental Assessment Program made some flow measurements and compiled a summary report of stream flow conditions in September 2000 for the Fisher and Carpenter Creek basins. Their assessment of the geology of the Fisher Creek basin was that the outwash deposits were overlain by a till layer. On September 21, 2000, they measured flows of 0.5 cfs in Fisher Creek and 2.2 cfs in Carpenter Creek. In other words, the flow in Fisher Creek was 23 percent of the flow in Carpenter Creek. As a comparison, Geomatrix' estimates of basin areas indicate the Fisher Creek basin area is about 32 percent of the Carpenter Creek basin area.

In contrast to the 2000 measurements, flows measured by Ecology in August and September of 2001 in conjunction with a TMDL study found flows of 0.65 cfs in Fisher Creek and 1.30 cfs in Carpenter Creek on August 6, and flows of 0.53 cfs in Fisher Creek and 0.68 cfs in Carpenter Creek on September 17. In other words, on August 6, the flow in Fisher Creek was 50 percent of the flow in Carpenter Creek. On September 17, the flow in Fisher Creek was 78 percent of the flow in Carpenter Creek. Again, these flows compare to a basin area for Fisher Creek that is about 32 percent of the basin area for Carpenter Creek.

As a further comparison, in Fisher Creek, the September flow was 78 percent of the August flow. In Carpenter Creek, the September flow was just 52 percent of the August flow.

The 2000 flow measurements and geology description would indicate that the Fisher Creek basin has groundwater capacity similar to Carpenter Creek with regard to maintaining low stream flows. The 2001 flow measurements would indicate just the opposite, that Fisher Creek has much higher groundwater capacity to maintain low flows than does Carpenter Creek, which would be consistent with Geomatrix' characterization of Fisher Creek geology. Both of these cases presume that the reported flows are substantially natural flows, that there were no significant diversions or artificial inflows occurring that would affect our hydrologic interpretations.

The 2001 TMDL study (page 53) treated the Fisher Creek and Carpenter Creek watersheds the same with regard to estimating low flow values. "The lowest 7-day-average flows during the July-August period with recurrence intervals of 2 years and 10 years were estimated based on low-flow statistics from the USGS gaging station in Pilchuck Creek. The 7Q2 and 7Q10 flows in the study area were then estimated by scaling the estimates at the USGS Pilchuck Creek gage according to the sub-watershed areas weighted by annual average precipitation." So, there is some precedent for Ecology to consider these two adjacent watersheds to have reasonably similar hydrogeology, with flow differences due primarily to drainage area and precipitation.

My conclusion from all this is that, in the absence of more definitive information to support using another surrogate gauged watershed, at this time I am reluctant to change from my previous recommendation to use the East Fork Nookachamps Creek watershed as a surrogate watershed to estimate low flows in Fisher Creek. I would be open to additional information that would help clarify and quantify the differences between Fisher Creek and adjacent Carpenter and Nookachamps Creeks. Also helpful would be information that would help indicate whether one of the other two gauged watersheds, Day Creek or Alder Creek, might be a better surrogate for estimating flows in Fisher Creek.

Alternate Approaches

14. *Overly simplified approach by Ecology*. *Recommend more sophisticated modeling*.

I agree. This was a simplified, quick analysis of the existing data and information. I also agree that detailed hydrologic modeling, including watershed instrumentation (precipitation and stream flow gauges), data collection and model calibration, would provide more definitive flow estimates that would in turn inspire more confidence in the calculated flow values.

Such a modeling effort, however, would take some time and financial resources to complete, especially if this is to be done for each sub-basin. Also, it is not known whether the results would significantly change the tentative conclusions from my analysis, or simply provide more confidence in the flow estimates we have now.

Until such time as the modeling efforts can be completed, these are the best estimates we have for low flows in the lower Skagit sub-basins. I recommend using these interim values until such time as the modeling efforts can be completed.

As mentioned in item 13, I would be open to additional information that would help clarify and quantify the differences between Fisher Creek and adjacent Carpenter and Nookachamps Creeks, or that would help indicate whether Day Creek or Alder Creek might be a better surrogate for estimating flows in Fisher Creek. When such information becomes available, it could be factored into revised interim flow estimates for Fisher Creek.

References

Cummans, J.E., M.R. Collings and E.G. Nassar. ***Magnitude and Frequency of Floods in Washington***. Open-File Report 74-336. U.S. Geological Survey. 1975.

Dragovich, Logan, Schasse, Walsh, Lingley, Norman, Gerstel, Lapen, Schuster and Meyers. ***Geologic Map of Washington – Northwest Quadrant***. Geologic Map GM-50. Washington State DNR Division of Geology and Earth Resources. 2002.

Drost, B.W., and R.E. Lombard. ***Water in the Skagit River Basin, Washington***. *Water-Supply Bulletin No. 47*. Washington State Department of Ecology and U.S. Geological Survey. 1978.

Pitz, C.F., and R.S. Garrigues. ***Summary of Streamflow Conditions, September 2000: Fisher Creek and Carpenter Creek Basin***. Publication No. 00-03-049. Washington State Department of Ecology, Environmental Assessment Program. December 2000.

Sinclair, K.A., and C.F. Pitz. ***Estimated Baseflow Characteristics of Selected Washington Rivers and Streams***. *Water Supply Bulletin No. 60.* Publication No. 99-327. Washington State Department of Ecology, Environmental Assessment Program. October 1999.

Soil Conservation Service. ***Soil Survey of Skagit County Area, Washington***. Soil Conservation Service. 1989.

Sumioka, S.S., D.L. Kresch and K.D. Kasnick. ***Magnitude and Frequency of Floods in Washington***. Water-Resources Investigations Report 97-4277. U.S. Geological Survey. 1998.

U.S. Geological Survey. ***Water Resources Data for Washington for Water Year ____***. Water Data Report WA-____. U.S. Geological Survey. [publication year]

Data for Water Year 1998. Report WA-98-1. Published 1999.
Data for Water Year 1983. Report WA-83-1. Published 1985.

U.S. Geological Survey. ***Water Resources Data for Washington, Surface Water Records for Water Year ____***. U.S. Geological Survey. [publication year]

Records for Water Year 1971. Published 1972.
Records for Water Year 1969. Published 1970.

U.S. Geological Survey. ***Surface Water Records of Washington for Water Year ____***. U.S. Geological Survey. [publication year]

Records for Water Year 1963. Published 1964.
Records for Water Year 1962. Published 1963.
Records for Water Year 1961. Published 1962.

U.S. Weather Bureau. ***Mean Annual Precipitation in Washington, 1930-1957***. Map M-4430. USDA Soil Conservation Service (Portland). 1965. Plate 2 in Cummans *et al*, USGS, 1975.

Williams, J.R., H.E. Pearson and J.D. Wilson. ***Streamflow Statistics and Drainage-Basin Characteristics for the Puget Sound Region, Washington***. *Volume II, Eastern Puget Sound from Seattle to the Canadian Border*. Open-File Report 84-144-B. U.S. Geological Survey. 1985.

Zalewsky, B., and D. Bilhimer. ***Lower Skagit River Tributaries Temperature TMDL Study***. Publication No. 04-03-001. Washington State Department of Ecology, Environmental Assessment Program. January 2004.

ATTACHMENT 3
Suggested protocols for estimating low stream flows
for ungauged sub-basins in the lower Skagit watershed

DEPARTMENT OF ECOLOGY
Water Resources Program / Dam Safety Office

August 24, 2005

To: File for Record / Jacque Klug, Skagit Watershed Lead

From: Marty Walther, Hydrology/Hydraulics Engineer

Subject: Low-flow computations for 2-year recurrence and for Fisher Creek sub-basin

In conjunction with the continuing dialogue regarding in-stream flows for the lower Skagit sub-basins, the various parties have requested an estimate of 7-day low flows with a 2-year recurrence interval for comparison with previous low-flow estimates for the 10-year recurrence interval. The parties have also requested reconsideration of low-flow estimates for Fisher Creek as compared to adjacent Carpenter Creek.

7Q2 Calculations

The calculations for 7-day, 2-year flows (7Q2's) are shown on spreadsheets *Skagit_gauges3.xls* and *Skagit_7Q2's.xls*. *Skagit_gauges3.xls* (7 pages long in 2 worksheets) shows the basic stream gauge data and flow statistics from USGS stream gauges in the project area, including CSM (cfs per sq.mile) values for the 2-year flows.

Based on these CSM values, 2-year flows for the various sub-basins (including Fisher Creek, as discussed below) are calculated in *Skagit_7Q2's.xls*. This spreadsheet is 8 pages long in 4 worksheets, with 7Q2's shown in the first two worksheets.

Fisher Creek

The reconsideration of flow estimates for Fisher Creek as compared to adjacent Carpenter Creek included a quantitative review of stream flow measurements taken in 2000 and 2001 in conjunction with a temperature TMDL study. My analysis of the flow data for Fisher and Carpenter Creeks for both cfs and CSM values is shown on the second worksheet of *Skagit_gauges3.xls*. My analysis focused on six pairs of flow measurements taken within the May to September time frame, considered to be most representative of base flow conditions. For these six pairs of flow measurements, CSM values for Fisher Creek average 200 percent of the corresponding values for Carpenter Creek.

The flow measurements taken in 2001 (five of the six pairs of flow measurements) consistently show CSM values for Fisher Creek significantly higher than for Carpenter Creek. In contrast, the flow measurements taken in September 2000 show Carpenter Creek with the higher CSM value. I do not have an explanation or hypothesis for this seeming discrepancy in measurements between calendar years, but the majority of the data do show higher CSM values for Fisher Creek, consistent with the hypothesis of more groundwater storage in the Fisher Creek sub-basin available to sustain higher base flows in Fisher Creek during low-flow periods.

I also noticed that, as flows receded during the summer of 2001, flows in Fisher Creek tended to be higher as a percentage of the flow measured the previous month as compared to flows in Carpenter Creek. I interpret this observation as also being consistent with the hypothesis of more groundwater storage in the Fisher Creek sub-basin available to sustain higher base flows in Fisher Creek during low-flow periods.

For purposes of quantifying the 7Q2 flow in Fisher Creek, the CSM and CSM/inch values for Fisher Creek are considered to be 200 percent of the CSM and CSM/inch values for Carpenter Creek, as shown in *Skagit_7Q2's.xls*.

If desired, this logic and approach may also be applied to estimating the 7Q10 flow in Fisher Creek. By using CSM and CSM/inch values that are 200 percent of the CSM and CSM/inch values for Carpenter and Nookachamps Creeks, the effect would be to double the 7Q10 flow previously calculated for Fisher Creek from 0.2 cfs (in *Skagit_7Q10's-MW2.xls*) to 0.4 cfs.

References

Pitz, C.F., and R.S. Garrigues. ***Summary of Streamflow Conditions, September 2000: Fisher Creek and Carpenter Creek Basin***. Publication No. 00-03-049. Washington State Department of Ecology, Environmental Assessment Program. December 2000.

Zalewsky, B., and D. Bilhimer. ***Lower Skagit River Tributaries Temperature TMDL Study***. Publication No. 04-03-001. Washington State Department of Ecology, Environmental Assessment Program. January 2004.